NWX-NASA-JPL-AUDIO-CORE

Moderator: Anita Sohus
March 14, 2017
2:00 pm CT

Coordinator: Excuse me, this is the conference coordinator. I'd like to inform all participants, today's conference is being recorded. If you should have any objections, you may disconnect at this time. Thank you and you may begin whenever you are ready.

Jeff Nee: Hello, everyone. Happy Pi Day and welcome. I'm Jeff Nee from the Museum Alliance and it's our great pleasure to host this telecon today. Thank you to all of you for joining us and to anyone listening to the recording in the future. Today, we'll be talking about the upcoming Exploration Mission 1. There are no slides for today's presentation but you should have downloaded the presentation video, or you can stream it on the Dropbox link, hopefully, and all that information can be found on the Museum Alliance and Solar System Ambassador sites.

If you have any problems at all, you can please email me at jnee@jpl.nasa.gov. As a final reminder, please do not put us on hold even if you have to step away, because some phones play holding music, which can disrupt the talk. Just be sure your phone is on mute so that no noises from your end can interrupt the speakers. If you would like to do one final check that you are, in fact, muted, you can now simply say your name right into the phone, right now, and I'll let you know if I can hear you.

Great, I love silence before a telecom. Our speaker today is Mike Sarafin. Mike Sarafin currently serves as the Mission Manager for Exploration Mission-1, EM-1, at NASA Headquarters. In this role, he assures the safety and efficiency of all aspects of the mission, including preparation, certification of flights, management, launch, flight, and recovery operations. During the operations phase of EM-1, he will serve as the mission management team chairman.

Prior to this current post, he served as a NASA flight director where he was responsible for overall safety and success during missions, while overseeing human spaceflight operations from mission control in Houston. And during this time, he led space shuttle, ISS, and Orion mission operations, including the maiden test flight of the uncrewed Orion spacecraft. So if you can, please hold all your questions until the end. Okay, with that, Mike, it's great to have you and take it away.

Mike Sarafin: Okay, I'm glad to be here. Can you hear me?

Jeff Nee: Yes, you sound great.

Mike Sarafin: Okay. So I'll tell you what I'm going to tell you here a little bit, and maybe stall for time for folks that are frantically trying to download the video. And we've got a new mission video that we're starting to roll out here that overviews Exploration Mission-1, which is the first integrated flight test of the Orion spacecraft launching the Space Launch System, the most powerful rocket in the world, that's currently in production, launching from America's Space Port at the Kennedy Space Center.

This mission is scheduled to fly in the late 2018, early 2019 timeframe and we're well into production of the rocket and spacecraft, and it's scheduled to be a 25.5 day mission.

So the video that you should be queueing up right now is an overview of that. It's a 25.5 day mission that covers our trajectory, how we leave the earth and go fly about the moon, and then come home, followed by all of the mission phases from rollout to recovery. So we'll go through the rollout to the launch pad from the vehicle assembly building. We'll go through the launch countdown, the launch phase, orbital insertion. We'll commit to a lunar trajectory, orbit about the moon, and then return the spacecraft home, splash down in the ocean and then recover it.

It's a really exciting mission to be a part of. It's the first of many of our new deep space exploration system, and this uncrewed flight test is going to enable us to fly astronauts on the very next mission, called Exploration Mission-2. So I want to see how well folks are at following instructions here. Once you get the video downloaded, make sure that you haven't hit play yet. You should be looking at an Earth with the moon off in the far background, and if not go ahead and kind of rewind or go all the way to the very beginning of this. [Time 00:01]

It's about a nine minute video, and as I'm talking through this, I'll basically do an active narration of it for you. So it's important that we're synchronized, because otherwise, if I'm talking about the orbit phase and you didn't hit play at the right time, you may still be watching the launch phase, so it could get a little asynchronous. We are working on a fully narrated version of this with audio in the background and that should be released here before too long publicly. So if you miss it today, hopefully we'll have a good video with narration for you available here in a couple of weeks.

So we'll go through a countdown for you. We'll do a three, two, one, and then hit play and when I do that, you should be looking at the earth and I'll talk you through our trajectory followed by rollout through recovery. Does that sound like a good plan?

(Patricia): Hey, Mike. This is Patricia. Perhaps while you're going through, if you, at occasion, let them know what minute and second where you are with the video, so if someone starts late maybe they can fast forward to the moment that you're at. It's just one more thing to do while you're talking, but it may help people keep up.

Mike Sarafin: Okay, I'll do my best to multitask that.

(Patricia): Good luck.

Mike Sarafin: Yes, so hopefully everybody is synced up here. This is one of the prices we pay for having a telecon and not a Skype or WebEx type feature but I'll roll with it here if you guys will. Let's see, so again, so we're going to look at a nine minute video here. It's covering a 25.5 day mission called Exploration Mission-1. So if you could get your cursor over the play button, we'll go through our countdown here and in three, two, one, play.

Okay, you're watching the mission trajectory. We're going to launch due east from the Kennedy Space Center in Florida at an inclination of 28.5 degrees and upon completing the first orbit, we'll commit to a lunar trajectory, orbit about the moon in what's called a distant retrograde orbit before returning home and splashing down in the Pacific Ocean off the cost of California. So that's our mission trajectory and I'm about 25 seconds into the video.

[Time 00:27] So now, we're at the pre-launch phase. We're rolling out from the vehicle assembly building and roll out signals that launch is near. Sitting atop the mobile launcher, the Crawler transporter moves along the Crawler Way toward historic Launchpad, 39B, at the Kennedy Space Center at a top speed of one mile an hour. After traveling the four miles to the Launchpad, the rocket and the spacecraft climb up a ramp and are positioned over the flame trench.

The mobile launcher is lowered onto support posts and the Crawler is rolled away to a safe distance. Once on the Launchpad, checks are performed and the launch date is set, and the teams are prepared for the mission that is about to occur.

[Time 01:13] It's sunrise on launch day. Engineers in the launch control center have already powered up the spacecraft and the rocket, and loaded the core stage with cryogenic fuel.

[Time 01:30] As the launch window open approaches, final checks are performed and when all systems are go, the terminal count is initiated. The big physics of launch are about to be put on full demonstration. Umbilical plates weighing hundreds of pounds await their cue to retract and clear the path of the rocket liftoff, some mounted on arms the size of tractor-trailers. The mighty core stage engines are prepared for engine start and thermally conditioned for the onrush of cryogenic fuel and the heat of ignition. And in 15 seconds sound suppression is activated and water cascades into the flame trench to dampen acoustic shock.

As the core stage engines achieve full throttle, booster ignition, the flame trench is flooded with fire. At first motion, the umbilical arms are retracted and power clear occurs in just seconds. At liftoff, the vehicle is producing 8.8 million pounds of thrust, lofting the vehicle weighing 5.75 million pounds and standing over 32 stories tall. It's headed to orbit, propelled by a pair of five segment boosters and four liquid engines and achieves a maximum dynamic pressure only 90 seconds into the mission, the period of greatest atmospheric force on the structure of the rocket. Thousands will gather in Florida to watch our shape get smaller, and smaller, and leave the space coast behind. In just two minutes into the mission, the flight boosters have consumed all of their solid propellant and then safely jettisoned. The rocket continues to guide itself to orbit with magnificent precision.

Just three minutes into the mission, we lighten the load by jettisoning the service module fairings, exposing Orion's solar arrays and just 40 seconds later, the launch abort system is jettisoned. It's no longer needed. Orion could abort safely at any time.

[Time 03:01] Now, I'm three minutes into the video. Liquid fuel is consumed in the eight minute climb to orbit and after all is consumed, the core stage engines are shut down. The core stage separates and the interim cryo propulsion stage [ICPS] with Orion continues its climb to orbit.

Along the way, it passes through the altitude of the International Space Station at 250 statute miles above the earth. During this first orbit, the solar arrays of Orion are deployed. It no longer needs battery power. It can produce its own. Orion's solar arrays are then positioned into a loadbearing position in preparation for the perigee raise maneuver to ensure an Earth orbit. The thrust necessary for the perigee raise maneuver is provided by the interim cryo-propulsion stage.

After the perigee raise maneuver, Orion's systems are checked, leading up to the translunar injection or the TLI burn. TLI occurs just an hour and a half into the mission and lasts approximately 20 minutes. It increases the spacecraft's velocity over 9,000 feet per second, a speed change faster than a rifle bullet travels. Orion is now committed to lunar trajectory just 90 minutes into the mission. Following TLI, the spacecraft adapter remains with the ICPS. It separates from Orion and the interim cryo propulsion stage performs a disposal burn followed by deployment of 13 cube sets, each with their own science and technology mission, and using the volume and performance of the rocket.

I'm at four minutes, 50 seconds.

[Time 04:58] In the meantime, Orion departs low earth orbit and it flies through the orbital debris field encircling the earth. Half the global positioning navigation satellites pass the communication satellites in geosynchronous orbit and through the Van Allen radiation belts, and into the deep space environment. Orion is entering an outbound coast phase. It's uniquely designed to navigate, communicate, and operate in this deep space environment. The outbound coast lasts four days to the Moon.

[Time 05:40] As we arrive at the Moon, the service module will be used to perform a lunar gravity assist maneuver to allow Orion to enter what's called the distant retrograde orbit about the Moon. Its closest approach will be just some 62 miles from the surface of the moon and able to distinctly see individual surface features, including craters. And as Orion flies around the far side of the moon, we'll lose all communication back on earth. Mission control will await acquisition of signal and as we lock on, a new generation will see their first Earth rise. The spacecraft is now orbiting about the Moon.

As we do this, we'll test systems in this deep space environment for over a week, and along the way, Orion will travel farther than any human capable spacecraft has ever gone. And at its farthest point, it will be some thousand times farther from Earth than the International Space Station at 270,000 miles away. Teams in mission control and at Naval Base San Diego will prepare for Orion's return home. The recovery ship will set sail for the recovery zone in the Pacific Ocean, and Orion will exit the distant retrograde orbit with another lunar gravity assist and service module engine firing.

[Time 7:00] Along the way, we'll adjust our trajectory to ensure that the earth, which is over 200,000 miles away, is hit with a precision target. We'll be aiming for the earth's thin atmosphere to allow a precision landing in the Pacific Ocean, another four days return coast home. As we approach the Earth, an important contribution by our European partners, called the service module, will have completed its task. Now, the service module is jettisoned and the crew modules separates. We'll orient the world's largest heat shield into the direction of travel prior to entry interface, which is about to occur at an altitude of 400,000 feet.

At entry interface, Orion will hit the earth's atmosphere, traveling at a speed of 24,500 miles an hour and decelerate at nine times force of gravity. The heat shield will protect our spacecraft from temperatures half as hot as the Sun, approaching 5,000 degrees Fahrenheit.

[Time 8:00] Orion will decelerate passing through the sound barrier and announce its arrival to the waiting recovery team with a sonic boom. And after peak heating, the protective thermal cover, called the forward bay cover, will be jettisoned. This exposes the parachutes and we begin a series of parachute deployments. The drogue shoots are deployed, designed to stabilize and slow the spacecraft, and in a period of less than 20 minutes, Orion will slow from a speed of Mach 32 to zero at splashdown.

Deployment of the three main parachutes signals the final phase. They slowly unfurl, suspending the 22,000 pound capsule and allowing it to gently descend to splashdown.

After 25.5 days, in a total distance travel exceeding hundreds of thousands of miles, a precision landing occurring in the landing zone right near the recovery ship.

[Time 9:22] After splashdown, Orion will remain powered for two hours to collect data on how hot the cabin temperature got following the heat of reentry. U.S. Navy divers will be deployed from the waiting recovery ship in small boats and as they approach, they'll initially inspect for hazards before hooking up tending lines and a tow line.

After they’ve hooked up the tending line and the tow line, they'll hook up the tow line to a winch in the well deck of the waiting recovery ship and use that to tow our capsule into the well deck. As it crossed the stern gate, the stern gate will be closed and the well deck will be drained, and we'll bring our ship home. And we'll do it all again with American astronauts on board on the very next mission.

So I hope you're proud of what we're doing today and we're on a path to fly this mission, again, as I said, in the late 2018, early 2019 timeframe. So with that, I'm happy to take any questions and I hope everybody stayed synced up.

Man: Nice job reading through it. One question, you mentioned that you'll do it all again at the next flight that will be with the astronauts on board. Will that use the same capsule or are there more than one Orion capsule being built and used at the same time?

Mike Sarafin: That's a good question. We're going to fly a number of capsules, at least initially. Each of the capsules will have more and more capability and the first one is being flown in an uncrewed configuration so it doesn't have things like seats, and displays, and controls, and the regenerative life-support system in it. We're really aiming to test the heat shield and just the critical capabilities associated with launch, and landing, and maneuvering in space on the first one.

So the second spacecraft is just beginning production, even though we haven't flown our first yet. Well, we've already flown Orion once but not into deep space. So before we fly EM-1, we've already begun production of EM-2, which was started this fiscal year, and the primary structure, it's in production. And we've got a lot of test work that we're doing to ensure that both through the flight test called Exploration Mission-1, but also through some ground testing, a lot of ground testing, that we'll be ready to fly astronauts no earlier than 2021, 2022 timeframe. So I hope that answers your question.

Man: So four years between EM-1 and EM-2?

Mike Sarafin: Closer to three. That's our current plan

Man: Has that EM-2 crew been named?

Mike Sarafin: It has not. We'll probably name the crew some two to three years out, certainly after we fly Exploration Mission-1.

Man: Thanks.

Man 1: Mike, can hardly wait until we light that candle but I've got two quick questions for you, sir. One, why recovery in the Pacific versus the Atlantic? And second, is there any dependency on the phase of the Moon with the flyby of EM-1? Do you guys care what the phase is, so forth, and thanks. Great program. Can hardly wait.

Mike Sarafin: Yes, good questions. I can't wait until we light the candle either. So I'll answer the splashdown piece and then I'll answer the phase of the Moon piece. So the splashdown piece, the spacecraft is capable of targeting a landing within basically a 100 mile by 20 mile zone anywhere. It is designed for water landing, so land landing is really not an option and it has to do with the speed of descent and the amount of stuff that you have to fly on it. Like if you were to do a land landing, you would have to have retro rockets to slow it down even further.

So the spacecraft is designed, it's mass optimized to be as light as possible while still being safe. So a water landing is beneficial from reducing the overall weight of the capsule. It could land in either the Pacific or the Atlantic. The two naval bases that have the type of capability that we want to recover the ship are primarily out of either the East or the West Coast. Norfolk, Virginia has the well deck ships, as well as Naval Base San Diego that we would use. But if you look at overflight and if you were either long or short on your landing or the weather was not good, you're overflying landmass because you orbit the earth from west to east when you launch.

So for the launch phase, it's beneficial to launch in an easterly direction because you can abort and splashdown in the Atlantic at any time. And then when you reenter, it's best to target a landing in the Pacific before you get to landmass because that leaves you -- your greatest abort or download options.

Otherwise you'd be coming in over land and then if you were to be short for some reason on the landing, you would have to do a land landing, which the capsule is not designed for. So that either forces you to target the normal landing further out into the ocean, if you were to target the Atlantic, or to just aim for the Pacific. So I hope that answers that question.

As far as the phase of the Moon, there's no constraint on that in terms of lighting. The spacecraft does have limitations with power production and at least for our initial design, we don't want to see eclipse periods, or periods where there's no exposure of the solar arrays to sunlight, greater than two hours. So if we were to have just the right alignment between the earth and the moon in our trajectory such that Orion wouldn't see power production on the solar arrays due to line of sight to the Sun for greater than two hours, we would not launch that day or we would modify the trajectory. We know when those days are and we'll plan around them. So I hope that that answers your question about the phase of the Moon as well. Good questions.

(Tim Cassidy Curtis): This is (Tim Cassidy Curtis), solar system ambassador. I've got a couple of questions. I did see the video. It was a little late, so I had to put a little time delay in my brain. Number one, how closely does this mission actually come to the old Apollo 8 mission? And secondly, what's the dimensions of the solar panels and their output?

Mike Sarafin: Okay. So how closely does this come to the old Apollo 8 mission. We're actually going to go farther from the Earth than the Apollo 8 did. Apollo 8 was what was called a free return trajectory, so it used the Moon's gravitational pull to kind of slingshot the capsule around while still maintaining enough gravitational pull on the capsule.

We're not going to do that on Exploration Mission-1. We're actually going to deliberately insert the capsule into what's called a distant retrograde orbit and it will fly near some of the Lagrange points at roughly 70,000 kilometers or 43,000 statute miles from the Moon. So we're going to go father and we'll take deliberate actions to enter this orbit. So unlike a free return trajectory, where you don't have to do anything to get slingshot back towards the Earth, the distant retrograde orbit you have to maneuver into and out of using the service module engines and you can thrust yourself out into this point where there's an equal gravitational pull between the earth and the moon, like I said, 70,000 kilometers away.

The solar array size on the service module, I do not have the numbers on that one. I'll just be up front with you. I know that's in the tens of feet. These are big solar arrays. They're in an X configuration. I could probably look it up by the time we're done talking but I don't have that information handy. [Each of the four arrays is 7x2 meters.]

(Tim Cassidy Curtis): The February 15 press release hinted about having a crew added to EM-1. Is that completely off the table?

Mike Sarafin: So there's a study being done right now to assess the technical feasibility of flying astronauts on Exploration Mission-1 as well as the cost and schedule required to make that happen. So we've been under fairly tight budget constraints. So our plan as it stands today, and our program of record, is to fly Exploration Mission-1 as uncrewed and our entire test plan is being built around that. And then off to the side is this study that's being done at the request of the presidential team, and the new Trump administration, to assess whether or not we could fly a crew.

No decision has been made on that yet. The study is still going on and we'll look to the new administration if they're willing to accept the risk and provide the resources both in terms of time and schedule, we'll go off and make it happen. But if they're not willing to accept what it's going to take, then we're going to stick to our current plan.

(Tim Cassidy Curtis): The original cost estimate was half a billion at flight. How close are you guys going to be to that?

Mike Sarafin: So we are actively working to reduce the production and operations cost over the life of the program. So some of the numbers you may have seen were the initial cost estimates that included the development in first unit cost. We do have a request for information and some proposals that were requested by our contractors to propose ideas on how to lower the overall production and operations cost. Those numbers are still being looked at and I don't have the latest on what the study is on that one.

Jeff Nee: Mike, going back to the human thing, you mentioned that the EM-1 right now as it's configured doesn't even have seats. So it would take a lot of effort to make it human ready, right? Mike, still there? No, maybe he got cut off.

(Tim Cassidy Curtis): I would suspect, (Tim Cassidy Curtis), solar system ambassador, I used to work the shuttle program. I would suspect that they just figure out what it would take in terms of time, money, and effort, and present it to the administration and say here, do you want to foot this bill? They'll either say yes or no.

Jeff Nee: Yes, but like you said, I'm assuming it's going to take a lot to make it human ready.

(Tim Cassidy Curtis): Yes, I would imagine the cost would be significant and the Trump administration is going to have to ask itself, do we want to get this done now or later.

Jeff Nee: Right.

(Tim Cassidy Curtis): And once he gets the bill, they're going to have to say it's worth it or it's not.

Jeff Nee: I agree.

Mike Sarafin: Hey, guys. I'm sorry. I had a phone glitch there. For some reason, I lost you for about 30 seconds.

(Tim Cassidy Curtis): That's okay. How'd you like our discussion?

Mike Sarafin: I only caught like the last sentence there, so I'm sorry.

Jeff Nee: Yes, so my question is that it's going to take a lot to make EM-1 human ready because you were saying that it doesn't even have seats yet as it's currently configured.

Mike Sarafin: A lot of the stuff is really just cost deferral because, like I said, we've been under a fixed program cost on a year-to-year basis. So we've had to defer certain things from time to time. Seats are not a hard thing to go after, as are a lot of the capabilities that I mentioned. It's just a matter of when you start rolling them in and what years they're phased in, in terms of cost. There is a lot of work to go off and test it. It’s just we deliberately set this up to be an uncrewed flight test. If we want to accelerate that, it's going to take quite a bit of effort to do it.

Jeff Nee: Sure, thanks. And I was going to ask about the reusability of the whole system. Is it just the SLS boosters that are reusable or -- because the crew capsule is not.

Mike Sarafin: We are actually looking at reusing the crew capsules. That is probably one of the few things that we will reuse. We are certainly planning on reusing the avionics out of the EM-1 capsule and reflying those on EM-2 as well as some of the other subsystems. Long-term, we are looking at reflying the capsules, the primary structures themselves. In terms of the SLS rocket, the boosters, and the core stage, and the upper stage, all those are one-time use and that has to do with just the performance that we're trying to demand from the overall system. We're trying to throw as much mass as possible to the translunar injection point, and if you start looking at reflyable or reusable capabilities, now you've got to withhold propellant as well as have a system, a landing gear system or some other system to land those on. And our flight rate is only about once a year at our highest flight rate. So the rocket itself is not planned for reuse.

Jeff Nee: That's interesting. I just assumed that it was the -- the boosters would be reusable, but okay. And then I know you said it was -- this was mostly for testing the critical systems, but is there any science instruments going up on EM-1 at all?

Mike Sarafin: Yes, if you look at the cube sats that are getting deployed from the interim cryo propulsion stage, there are technology demonstrations as well as science missions. There's 13 of them in total. One of my favorite ones that's flying is an experiment that flies yeast, like brewer's yeast, and it will fluoresce if it's exposed to radiation and that will allow us to understand and monitor the deep space radiation environment. And there's any number of other experiments.

We are flying radiation area monitors, a number of them, in the capsule to understand what the crew members will experience when they fly through the Van Allen radiation belts, as well as in the deep space environment, which is very different than low earth orbit.

When we're in low earth orbit, you're within the protection of the earth's magnetic field and when you exit that magnetic field by flying into deep space out towards the moon or beyond, you no longer have that protection. So the low energy cosmic particles are out there, and they're normally deflected by the earth's magnetic field and we don't have to deal with them here, but our astronauts in space are going to have to deal with them. So we're trying to characterize that environment as well as demonstrate some new technologies, kind of some high risk, high return capabilities for the cube sats.

Man: Are you getting much data out of the old Apollo program? Is that helpful to you at all?

Mike Sarafin: Yes, absolutely. In fact, we still reference some of the operational techniques and procedures used. They also did a water landing, water recovery of the astronauts. We still have a few of those folks around as well as the operational data. Physics is still physics and math is still math, and that hasn't changed since the Apollo program. So we do go back and look at throw masses to translunar injection point, some of the orbital characteristics about the moon, some of the reentry velocities are very similar to what we're doing on Exploration Mission-1. Eleven kilometers a second at reentry or Mach 32 is our reentry speed and in doing burn targeting and setting up for a landing zone and all that other stuff, there's a lot of similarities. That technology, if we wanted to reproduce an Apollo capsule, we couldn't do it today because almost all the vendors are gone. They used vacuum tubes and there was no such thing as an LED or a circuit card back then.

So things have advanced and some of the core physics and math are the same but the technology has changed dramatically. So we've got to figure out how to make today's capabilities apply using knowledge that we've had for a little while.

(Tim Cassidy Curtis): Are the cube sats just for this first mission or is that something that's going to be on all of these?

Mike Sarafin: The cube sats on this mission are the only ones that we officially have manifested, and when I say officially manifested, that means the agency has committed to flying them and committed the resources to do them. We do expect to fly cube sats again in the future, but again nothing has been officially manifested. The SLS rocket itself is very unique in that it's going to be able to fly the largest payloads flown period, ever, in terms of volume as well as mass. So we're going to take full advantage of that capability and in some cases, we're going to fly very large payloads that are co-manifested with a crew in the Orion capsule. So you'll have the crew in the Orion capsule sitting on the nose of the rocket and then just below that, a co-manifested payload.

Apollo did something similar in what was called the trunk, and they extracted the lunar landing module out of the trunk with the command module. We will probably fly things like a propulsion and power bus, and a habitation module that we'll position out in the vicinity of the moon and use that as our space gateway in the future to go off and jump off to other deeper space destinations like Mars. So there's payloads and then there's really big payloads and we can do both with the space launch system.

(Tim Cassidy Curtis): So the SLS has been advertised as basically our vehicle to Mars. However, if the administration were to turn around and say, okay we can do Mars, but I want this thing to put something back onto the surface of the Moon. How easily could the SLS be repurposed to do that?

Mike Sarafin: Again, the physics and the capability of the rocket support it. You've got to have a couple of things. You've got to have the lift capability to get out of earth orbit and then you've got to have the throw mass capability to leave the earth's gravitational field and achieve what's called escape velocity, so that you can either go to the moon or go to another destination. There are other rockets that have the ability to achieve escape velocity, but not for the amount of mass or the volume that we're talking. The space launch system is essentially a super heavy lift class vehicle and right now, this would be the only vehicle in production that's capable of doing that.

And when you start considering we're flying humans, there's two aspects to that. One is humans have to have living volume and living space. So you have to be able to fly objects up to 8.4 meters across or roughly 25 feet in diameter and launch those safely, get them out of the earth's atmosphere. That's a really big thing to strap to the nose of a rocket. So there's that aspect of it, to provide the living volume for the astronauts when they're in space.

The other aspect of it is the rocket human rated or man rated, and what I mean by a human rating of a launch vehicle, you design additional levels of redundancy and fail safes into it such that if one thing goes wrong, the rocket is still capable of flying without losing the crew. And there are vehicles that have similar performance characteristics but they're not necessarily human rated. And when you human rate it, it's certainly a more complex vehicle. It's a more expensive vehicle because you're building safety features and redundancy and additional capability into it. So you've got to factor that into the overall what is your payload, and when the payload is a human you set a higher bar on what you're capabilities need to be on the rocket.

Any other questions?

Jeff Nee: I had a quick question about the timeline. If I remember, the timeline of the mission seems a little longer than the Apollo missions that were manned. Does EM-2 seem like it's going to have about the same timeline of a week or more at the moon?

Mike Sarafin: So EM-2, our first crewed flight, is going to be roughly eight to nine days in duration. It will be similar to Apollo 8 and it will be a free return trajectory. We're actually intending to fly a more technically challenging mission, from a rocket and a spacecraft standpoint on EM-1, to kind of test the outer bounds of the system before we put humans on it, on the next mission. And then we'll not take as much risk on the second mission because, again, we're flying humans on it. But we're also adding a lot of capability on EM-2. We're adding the displays and the controls, the human to machine interface, the life support system, the space potty. We're adding a lot of different capabilities inside the capsule that on Em-1 are taken up by things like radiation area monitors that are helping us characterize the environment we're going to put astronauts on, on the very next mission.

We're putting a lot of instruments on this thing to make sure that we understand, from a stress, and strain, and radiation environment, and acoustic shock, and loads, standpoint, that our models on the ground are good, and that we understand what we're committing to in terms of the safety of our astronauts before we actually ask them to step on board.

Earl Kyle: Questions?

(Earl Kyle): Hello, can you hear me?

Mike Sarafin: Yes, go ahead.

(Earl Kyle): Yes, this is (Earl Kyle) in Rochester, Minnesota, a solar system ambassador. A couple years ago when the Orion capsule was launched on delta heavy, I think, there was some student experiment inside the Orion capsule to test for effectiveness against radiation. Do you guys plan on doing something similar like that by inviting students to put something inside the Orion capsule on this EM-1 mission since you're not going to have the displays and the seats. There'd be enough room to put stuff in there.

Mike Sarafin: Yes, we essentially have done that through the cube sats that I talked about. Like I said, there's 13 different science and technology missions that we're committing to fly and then we've got some partnerships with academia. There's a couple of different universities that are planning on flying a cube sat that we're going to launch.

Inside of Orion, we're looking at partnerships with our international partners at the European Space Agency as well as the Japanese Exploration Agency and a few other potential strategic partnerships. If there is space or mass available, and time and money available, we'll go off and add some other science experiments. But as you're aware, time and money are limited, and our intent is to primarily to fly the rocket and the spacecraft on time and fly it safely so that we can start flying crews as quickly as we can.

(Earl Kyle): Thank you.

Jeff Nee: And Mike, I just have one final general question. I mean, being on this project and being at the forefront of human space travel and deep space, in your mind what is the number one most, I guess, adamant obstacle to us going to settle the moon, or settle Mars. Is it really just about money or do we need something? Or is there something that we really need to figure out before?

Mike Sarafin: So there're a couple of different ways to answer that question. Technically, we've got probably 90% of what we need to go off and do it, and then it comes down to dollars. There are a few technical hurdles that we wish we knew more on, and we wish we could do better, and I'll come back to those in just a minute. But the other piece of it is really just the stability and long-term policy and having the intestinal fortitude to commit to a generational, or a generation long, or a multi-decadal program and sustain that over a long period time, and resist the temptation to change and/or re-vector.

I personally am somebody that - I'm here to serve. I'm an instrument of policy. I don't set policy and I'll be glad to go off and implement whatever direction we're asked to go off and implement. But over time, policy can and occasionally does change and it could mean one thing or another in terms of where we're going or what capability we use. But because these types of programs take so long to safely design, and then produce, and then test, and then fly before you get to a stable cadence; and our political system has a shorter half-life, on the order of four or eight years; and the development cycle takes anywhere between seven and ten years, it makes it hard to maintain a stable path forward.

And that's just the reality of what we're in and we do our best to kind of dampen that noise out and stay on a stable course. But occasionally, we are asked to go off and move in a different direction. So that's probably one of the bigger hurdles with policy comes dollars, right? Because if you want to understand where somebody's priorities are, you look where they're spending their money. And I think NASA gives a pretty good return on investment to the taxpayer. Right now, we're less than one half of 1% of all federal spending as an agency. So if you were to take a dollar and turn those into pennies, and you were to cut one penny in half, that's how much NASA's budget is out of that tax dollar.

And that’s the entire NASA portfolio. So that is human spaceflight, which I work, and I'm working exploration, but there's also International Space Station, there's also commercial crew, there's also commercial cargo. But then there's the science portfolio that NASA has. There's the helio-physics portfolio where we look at the sun and its behavior over time, where you look at deep space and interplanetary. We've recently explored Pluto. It's the first time it's ever been done. We've explored all planets and dwarf planets now within our solar system [except for Eris, Haumea, and Makemake]. We've got probes going about Saturn right now. Cassini is about to achieve its end of mission.

We've got rovers and orbiters on Mars right now, robotically exploring Mars, and we have earth observation satellites looking at ocean surface temperatures, and ozone, and land use patterns, and all those things. So that's the entirety of NASA's budget and I work on just one portion of that. So in terms of investment, I think you get a pretty good return on your investment, but it's maintaining that stability and what we're doing with those dollars and invested over time that I think is one of our bigger challenges.

And again, it's because these things take years if not a decade to build, and safely develop, and have reproducibility in terms of production.

Technically, there's a few things that are challenges to us, specifically flying in the deep space radiation environment. We know we can do it, but doing it for a three-year period, because it'll take astronauts nine months to go outbound to Mars, just one way travel time, and then nine months to get home, that's 18 months and you want to make it worth your while and stay there for some period of time. So you're talking anywhere between a two and three-year mission and exposing humans to the deep space radiation environment where you don't have the advantage of the earth's magnetic field to protect you. So you've got to come up with some other protection mechanism.

We haven't characterized the effect of deep space radiation on the human body very well. We want to continue to get more information on that and it is a priority for NASA, but also logistics. When you're now days or weeks from Earth, it's four days to get to the moon. When you're there or even farther, what do you do for supplies and life-support -- consumables like oxygen or water. What if you start running low? It's one thing to return to earth an hour and a half away because you're on the space station. It's another thing to return days or weeks away.

So the farther you go, the harder your supply chain gets to be. So we're looking at instituting and implementing repair and manufacturing technologies using 3D printing and how do you repair your spaceship using a 3D printer. How do you recycle water and oxygen like you’ve never recycled before. We're demonstrating the technologies right now on the space station, but we want to -- instead of get a 70% return of water and oxygen like we're getting on the system now, we want to get up into the 90% so that we're throwing away very little of our precious oxygen and water for life support.

Those are the types of things that get to be really challenging, technically, the further you move away from earth. So I hope I answered your question there.

Jeff Nee: Yes, that's a great answer and I ask because I get asked that all the time by kids of "when can I go to Mars," basically, and I never thought about the stability of the politics before. So that was really interesting for me. So thanks for that. Because when I'm doing a class full of third or fourth graders will be the right age, in the 2030s, to go to Mars, I need to find something to say to them. So thanks. That's really helpful.

(Earl Kyle): Mike, I have one last question. It's (Earl Kyle) again. I was 2.8 miles away from Pad 39A when Apollo 11 took off and I've heard that this SLS is 40% more powerful than a Saturn V. If I were in that same spot when you light the candle on this sucker, would I survive?

Mike Sarafin: So I don't think they'll let you be two point something miles away. On this one, unlike Saturn, which was a liquid rocket, this is a hybrid liquid and solid propellant rocket. And there's a clear zone, it's either three or four miles. I can't remember what they said on this one, but you're going to definitely feel it more. A rocket that has a solid propellant or a solid propulsion system is definitely louder than a liquid system. So like if you saw the Saturn rocket or if you've seen an Atlas launch, those are all liquids. That has a different sound and feel than the space shuttle, which was part solid, part liquid, or the Delta class, or the Titan class launch vehicles, some of which have solids.

The solid have a crackling sound to it when it launches and it creates a larger acoustic shock so you definitely feel it in your chest more. That's nothing against the liquid engines or liquid propellants and turbo machinery guys out there, because they do some pretty awesome work. It's just you just don't feel it in your body and your bones as much.

(Greg Riftman): Mike, it's (Greg Riftman). A quick comment. I've got a video on YouTube of the LADEE (Lunar Atmosphere and Dust Environment Explorer) launch that used the repurposed peace keeper solid rockets, the intercontinental ballistic missile, and you go to that, and you watch that and you see what a fairly small solid could do. But it was impressive, let me tell you.

Mike Sarafin: I'll tell you, I was at the Kennedy Space Center in 2010 when the Ares 1-X suborbital flight test occurred, which was essentially a five segment shuttle solid rocket booster with a payload attached to the nose of it that they went up to 200,000 feet and then came back. I was standing at the Kennedy Visitor Center at the Banana River location, and watching that launch -- and I remember feeling it, but somebody that was with me tapped me on the shoulder and said, Mike, you need to turn around and look at the building behind us. And I'm like no, I'm going to watch this launch. And they're like no, you need to turn around and look at the building behind us.

And if you've ever been to the Kennedy Visitor Center, you know that the backside of that as it faces the launch pad is all glass and it's like four stories tall. And the glass on that thing was rippling back and forth like the surface of the ocean and it was purely from the acoustic shock and the sound and vibration of that Ares 1-X rocket. And I've never ever seen that before. I thought the windows were going to break on the thing, they were moving that much. So that put it into perspective for me.

Man 3: You light a solid you're going someplace. That's the bottom line.

(Tim Cassidy Curtis): This is (Tim Cassidy Curtis). I want to put it into perspective that the NASA spending, and yes, I wish a study would be done on the effect of NASA spending on the overall U.S. economy. I think the results would be remarkable. However, when you talked about one half of 1%, the United States actually minted a one half cent from 1793 to 1857. So you can tell them that compared to a dollar, NASA spending is one half cent, which the United States actually minted.

Now, I'm going to switch subjects on you. I'm looking at the evolved [SLS] configurations. Can you tell me -- I'm looking at the Block 1, Block 1B, and Block 2. Do you know which ones are going to be the heavy-heavy 130 ton?

Mike Sarafin: Yes, that will be Block 2. So we're -- Exploration Mission-1 is flying the Block 1 or the 70 metric ton version. Exploration Mission-2, the first crewed mission is going to be the first Block 1B flight, or the 105 metric ton version. And we're going to fly the 105 metric ton, or Block 1B version. Our plans right now have us doing that until the end of the 2020s and then we'll go to advanced boosters and fly the Block 1B, I'm sorry, the Block 2 configuration or the 130 metric ton.

But even Block 1 or Block 1B, it's a significant advancement above both the throw mass to earth escape velocity, but also the volume of payload that you can throw to that distance, compared to any other vehicle that's in production out there.

And again, we're aiming to fly humans and provide them with living space and what they need to explore deep space.

(Tim Cassidy Curtis): All you say is true. I will let you know, though, that Apollo 8 put 148,770 kilograms into orbit.

Mike Sarafin: Okay. That's a lot.

(Tim Cassidy Curtis): Yes, that's the most in a single lift. I'm doing currently an unpublished paper on it.

Jeff Nee: Well, look at that. That was a great way to spend an hour. We do want to be respectful of everyone's time. Mike, thank you so much. We all really, really appreciate the time you took for us and we love the video. Any last second questions for Mike? Great. Okay, of course, like I said before, if you have questions later or for anyone who's listening to the recording in the future, if you have questions just email us, either myself, Jeff Nee, or Kay Ferrari, if you're an ambassador and, we'll get you the information that you need. Thank you for everyone for joining us today. This was a really great topic and remember that you're encouraged to share this presentation with your colleagues like your education staff and museum docents.

The different networks have a slew of talks coming up. We have a history of women astronauts tomorrow evening from the Night Sky Network and we have resources for your 2017 eclipse events on Thursday from Earth to Sky, and on Friday the 24th, that's next Friday [rescheduled to Thursday the 23rd], we'll have live coverage of the lunar and planetary science conference from the ambassador's team.

We hope you and your staff will join us on any or all of them. As always, the most up-to-date information as well as the archives of all the talks afterwards will always be on our websites and you can email us with any questions. Once again, my name is Jeffrey Nee and my email is jnee@jpl.nasa.gov. And we all wish you a Happy PI Day. Thanks again to Mike from NASA headquarters. Anything else you want to add?

Mike Sarafin: No, I just wanted to thank you, Jeff, and thank Patricia for helping to facilitate and get us all set up. I hope you guys enjoyed it. I was glad to come back and talk to all of you again and I certainly appreciate your interest and enthusiasm, and for all of you, keep doing what you're doing. It's important. Thank you.

Jeff Nee: Thanks everybody. Have a wonderful day.

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